# Mobility, Productivity and Patent Value for Asian Prolific Inventors : China, Japan, Korea and Taiwan, 1975 - 2010

William Latham, Christian Le Bas, Dmitry Volodin

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**GATE Groupe d'Analyse et de Théorie Économique Lyon-St Étienne**

93, chemin des Mouilles  69130 Ecully – France
Tel. +33 (0)4 72 86 60 60
Fax +33 (0)4 72 86 60 90

6, rue Basse des Rives 42023 Saint-Etienne cedex 02 – France
Tel.  +33 (0)4 77 42 19 60
Fax. +33 (0)4 77 42 19 50

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**Mobility, Productivity and Patent Value for Asian Prolific Inventors: China, Japan, Korea and Taiwan, 1975 – 2010**

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William Latham
Department of Economics,
University of Delaware,
Newark, Delaware 19711, USA
latham@udel.edu

Christian Le Bas, Université de Lyon, Lyon, F-69007, France ; CNRS, GATE Lyon Saint-Etienne, Ecully, F-69130, France, Université Lyon 2, Lyon, F-69007, France.
christian.lebas@univ-lyon2.fr

Dmitry Volodin
HDR Inc., Silver Spring, MD, USA
volodin@udel.edu

Abstract
We provide new insights into the role of individual inventors in innovation. We focus our analysis on *prolific* inventors in China, Japan, Korea and Taiwan. We analyse patents issued by the U.S. Patent and Trademark Office to thousands of inventors from those countries between 1975 and 2010 to investigate the role that mobility plays in the behaviour of prolific inventors. We hypothesize that mobility affects: (1) the productivity of prolific inventors and, (2) the value of their inventions. We compare findings for each of the countries with those for inventors in North America, Western Europe and Australia & New Zealand.

Résumé
Dans ce papier nous donnons de nouveaux éclairages sur le rôle des inventeurs dans le processus d'innovation. On se concentre sur les inventeurs prolifiques de quatre pays (Chine, Japon, Corée et Taiwan. On analyse des brevets déposés à l'office américain des brevets (U.S. Patent and Trademark Office) de 1975 à 2010 pour investiguer le rôle que la mobilité joue dans les comportements des inventeurs prolifiques. On fait l'hypothèse que la mobilité affecte: (1) la productivité des inventeurs et, (2) la valeur de leurs inventions.

Key words: Innovation, prolific inventor, inventor productivity and mobility, patent.

JEL codes: D22, J24, O15, O31, O32

## 1. Introduction

This paper provides new insights into the role of individual inventors in innovation. Individuals are central in this creative process because innovation is not simply a product of firms and organizations, it requires individual creativity (Rothaermel and Hess, 2007). We focus our analysis on *prolific* inventors (a rich sub category of inventors) because they contribute so hugely to national invention totals (Le Bas *et al.,* 2010) and tend to produce inventions that have more economic value (Gambardella *et al.,* 2005; Gay *et al*., 2008).[1]

Previous studies of prolific (or "key") inventors have focused more on the firms in which they work or on the industries in which the firms operate. Narin and Breitzman's (1995) seminal work on the topic is based on an analysis of only four firms in a single sector and a recent paper by Pilkington et al. (2009) uses only two firms. In contrast to these studies on small samples, we use a very large data set which includes thousands of inventors in thousands of firms in China, Japan, Korea and Taiwan to estimate the determinants of inventive behaviour at the individual inventor level and the scale and scope of innovative activities at the country level.

We investigate the role that mobility plays in the behaviour of prolific inventors. We hypothesize that mobility affects: (1) the productivity of prolific inventors (as measured by their average number of inventions per year over their active inventive lives) and, (2) the value of their inventions (measured as the numbers of citations a patent receives in the years after it is issued). Our data come from patents filed by inventors from each of the countries in the US Patent and Trademark office during the period from 1975 to 2010. While we focus on the activities of prolific inventors, our data set includes all inventors so the unique characteristics of prolific inventors can be identified.

The scale, determinants and effects of inventor mobility have been analyzed recently by Hoisl (2007 and 2009), Schankerman *et al.* (2006), Tratjenberg (2004) and Tratjenberg *et al.* (2006) among others. Hoisl, using European patents and a survey of 3049 German inventors, finds that an increase in inventor productivity, measured as the number of patents per inventor, decreases the number of moves. She tests the causality of productivity of inventors on inventor mobility and finds that *more productive inventors are not more mobile*. For Hoisl (2007), a move increases productivity but an increase in productivity decreases the probability of observing a move. Schankerman *et al*. (2006) have studied the mobility of inventors using patents in the software industry in the US. Their findings are in accord with Hoisl's: they show that the very productive inventors have a decreasing probability of moving between assignees as their careers progress (Schankerman et *al.,* 2006; 26).

We have extended these studies in our prior work (Le Bas et al., 2010; Latham et al., 2011) by considering prolific inventors in several countries, using several indicators for productivity and several indicators of the value of inventions and three kinds of mobility. We measure inventor mobility in three dimensions: across companies ("inter-firm mobility"), across technologies ("intellectual or technology mobility") and across regions ("geographic mobility"). We provide systematic analyses of the relationships among mobility, productivity and value of inventions (measured by patent citations) for prolific inventors. For each country we have estimated equations for productivity, value and mobility. As far as the determinants of inventor productivity, mobility and invention value are concerned our results from a study of Germany, France, and the UK show (Latham *et al.,* 2011):

1) In all three countries productivity is positively related to inter-firm mobility. Temporal concentration of patenting is also positively related to productivity. However, for France, productivity is negatively related to geographic mobility.

2) For all three countries value of invention (as measured by citations per patent) is positively related to productivity. For UK and Germany the equations show consistent positive and significant

[1] Previous papers have justified the identification of prolific inventors as those who have been issued at least 15 patents.

relationships between value and inter-firm mobility (by contrast the coefficient is not significant for France).

3) The mobility equations show that productivity is positively associated with mobility and value is negatively associated with it. Inventor technological specialization is also negatively related to inter-firm mobility while the temporal pattern of inventing seems to be unrelated.

The paper extends the previous results in several dimensions:

1) By focusing on Asian countries (China, Japan and Korea and Taiwan) we are able to test whether the determinants of inventor productivity and mobility are the same in Asian countries. We make detailed comparisons regarding patenting in China, Japan and Korea and Taiwan. These comparisons permit analysis of the degree to which these Asian countries differ from each other.

2) We now take into account geographic mobility and test its impact on inventor productivity.

3) We utilize a new data set covering a longer time period (1975-2010)

## 2. Setting the scene: Technological advance in Asian countries

In this section we review some aspects of the evolution of research and development and technology activities in Asian countries. Economic models show that productivity growth at the country level can be explained not only by increases in capital per worker, but also by technological advance. Recently attention has been paid to the mechanisms of technological change in countries that were originally well inside their frontiers. Many economists have acknowledged that the accumulation of capital per worker (including human capital) is not sufficient to explain the rapid growth of Asian countries. They stress the economic importance of the acquisition and assimilation of foreign advanced technology. This requires not only the accumulation of physical and human capital but also requires risk-taking, entrepreneurship, effective learning, creative imitation, public policy supporting knowledge activities and birth, and development of industrial firms capable of produce technologically complex products (Kim and Nelson, 2000; Nelson and Pack, 1999).

**Table 1: R&D and Patenting Activities for 8 Countries**

| | R&D/GDPa (2006) | % Financed by industryb (2009 or latest year available) | Patent Applicationsc (2008) | Foreign-oriented Patent Familiesc (2003-2007) | Resident Patent Applications per $ Billion GDPc (2008) | Patents Grantedd (2009) | Total Researchers full time equivalent (2009 or latest year available) |
|---|---|---|---|---|---|---|---|
| UK | 1.8 | 45.4 | 42 296 | 95 990 | 7.9 | 3175 | 235 373 |
| France | 2.12 | 50.7 | 47 597 | 123 621 | 7.5 | 3140 | 229 130 |
| Germany | 2.5 | 67.3 | 135 748 | 340 885 | 17.8 | 9000 | 311 500 |
| US | 2.65 | 67.3 | 400 769 | 1 046 874 | 17.8 | 82382 | 1 412 639 |
| Japan | 3.2 | 78.2 | 502 054 | 785 762 | 82.2 | 35501 | 656 676 |
| Korea | 3.1 | 72.9 | 172 342 | 210 139 | 102.6 | 8762 | 236 137 |
| China | 1.45 | 71.7 | 203 487 | 28 505 | 26.6 | 1655 | 1 592420 |
| Taiwan | 2.57a’ | 70.4 | | | | 6642 | 110 089 |

Source : (a) Eurostat and OECD MSTI, (a’) National Science Council, R.O.C. (Taiwan), Indicators of Science and Technology, Taiwan, 2009 (b) MAIN SCIENCE AND TECHNOLOGY INDICATORS: VOLUME 2010/2,OECD 2011. (c) WIPO, World Intellectual Property Indicators. 2100 Edition. (d) USPTO.2 (e) MAIN SCIENCE AND TECHNOLOGY INDICATORS: VOLUME 2010/2, OECD 2011

[2] The WIPO criterion for allocating patent applications to a particular country is the residency of the first-named applicant. Applicants may file patent applications for their inventions in multiple jurisdictions, leading to some inventions being counted more than once in patent counts by office or by country of origin. To correct for this, various institutions releasing statistics use a new indicator the so-called patent families, defined as a set of patent applications interlinked by—or a combination of—priority

In Table 1 we provide information about the size of R&D and technology activities through different indicators for eight countries. Table 1 shows that, in terms of R&D expenditures intensity (the ratio R&D/GDP) the Asian countries (China except) have caught up to the European countries. China's R&D intensity is still weak but has strongly and steadily increased from 0.83 in 1999 to 1.31 in 2003. In a few years it should reach 2% and be comparable to European levels.[3] A common feature to the Asian countries is the importance of R&D financed by the business enterprise sector. Technological innovation capabilities no longer are concentrated in the European Union, USA and Japan. Korea and Taiwan in recent decades and China now have developed strong significant technology sectors. Due to the lack of harmonization between the different national intellectual property offices, it is more difficult to compare national technological strengths through patenting. According to a recent WIPO report, Korea, Japan and China are the top-ranked countries in terms of resident patents-to-GDP and resident patents-to-R&D ratio. The data related to foreign-oriented patent families provide a more balanced view. The level of patenting in the US system of patents indicates that even though the US and Japan continue to run far ahead, Korea and Taiwan have levels of patents granted comparable to those of Germany, the top European country (and larger in terms of economic activities and population). China remains behind. Note that the countries under observation are different in size as far as R&D activity is concerned (see the last column of Table 1).
We previously studied five "old" larger economies as far as the population of inventors is concerned (Latham et al., 2010). Here we provide more information on the specific patterns of technological accumulation evolved in Korea, Taiwan, and China that is distinct from that of countries with longer technology development histories. In the past, Korea and Taiwan depended on foreign technology through the import of capital. New analyses of patent data have shown evidence revealing that these countries have become the technological equals of the previously more-advanced countries (Hayashi, 1999; Mahmood and Singh, 2003; Tokomaru, 2009). The construction of technological capacities in Korea followed the model proposed by Kim (1997): a gradual and sequential change with the passage of firm strategies from "imitation to innovation" (the importance of gradualism has been noted as well by Hobday, 1995).

In contrast with technology developed in huge industrial conglomerates in Korea, in Taiwan technological development has been mainly due to the dynamism of small and medium enterprises supported by a government that funds R&D and helps to transfer its results to Small and Medium-sized Enterprises (Odajiri, 2006). The Taiwan Electrical and Electronic Manufacturers' Association has actively assisted its member to upgrade manufacturing technologies and expand international marketing competences (Intarakummerd, 2006). The Taiwanese system of production is based on smaller and more flexible production systems with less capital intensity (including the computer industry) than in Korea (Gu and Lundvall, 2006). Without denying an important role to government efforts Saxenian (2003) suggested that

> the dynamism of Taiwan's IT industries, like those of Silicon Valley and its other 'imitators,' is rooted in the incremental deepening and broadening of the capabilities of a localized cluster of specialist producers as well as in its close economic ties to the original Silicon Valley. This differs fundamentally from the privileged relationship between the state and a handful of large, established corporate giants that characterized IT development in Japan and Korea in the 1980s. If the East Asian case is viewed as state-led development, then the experience of Silicon Valley, Taiwan, and its other 'imitators' is best understood as entrepreneurship-led growth."

As in Silicon Valley, high levels of inter- firm mobility enables the diffusion of tacit knowledge and facilitate the process of new firm formation (Saxenian, 2003).

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claims (see WIPO). Due to the fact that it is difficult to compare the patent data coming from different national institutions (for instance we understand that the Japanese Patent Office authorizes several applications for the same invention), we provide in the last column the numbers of patents granted by country using the USPTO data. These latter are, at least consistent, and may provide a better basis for making comparisons of country relative values.

[3] In Europe the Scandinavian countries have the highest R&D expenditures intensity, comparable to the Japanese level.

Latham and Yin (2009) use Chinese domestic patent statistics to show how China has developed technologically over the past twenty years (1985-2004). They find that overall patenting activity seems to have an S-shape over the past twenty years. Innovation activities are particularly low in terms of growth rates and patent intensities for the years 1993-99, perhaps due to the shock caused by industrial reforms. Second, patenting activities seem to be increasingly oriented toward the IT sectors in the most recent years. Finally, they remark that China's overall improvement in technological strength over the past twenty years is modest. Gu and Lundvall (2006) using the institutionalist framework delineate the main transformations of the Chinese "national system of innovation". By 1980 "a large number of previously government-run industrial technology R&D institutions have transformed to be closely associated with industrial production" (Gu and Lundvall, 2006). At the same time, the innovation system is becoming more open to international exchanges of technological knowledge. The IT industry has been restructured from a military-oriented to an application-oriented system. In this context the dominant technological strategy continues to be based largely on imitation. Foreign enterprises both contribute to and draw on the pool of local talented people, particularly in R&D activities (Altenburg et al., 2008). Sun (2002) argues that in-house research and development (R&D) efforts, rather than imported technologies, are the primary sources of industrial innovation in China. He notes as well the limited efforts to absorb imported technologies; this is a serious barrier to fulfilling the potential of these technologies and to upgrading China's internal creative capabilities. However, Sun's period of observation ends in 2000).

The impact of multinational corporations (MNCs) on the local formation of technological capabilities works strongly in this context. This role has been exemplified by Ernst and Kim (2002) through the concept of the "global network." This network is built up by MNC integrating dispersed supply, knowledge, and customer-provided new opportunities for capability formation by local suppliers in developing countries. As a consequence local suppliers have a strong incentive to internalize transferred knowledge. But this process of transfer is not automatic: local firms need to upgrade their own absorptive capacity and increase the effectiveness of capability formation. To stay on the global network, local suppliers must tap, develop, and retain highly-skilled human resources. Global networks act as mediators in the building up of the technological capability of local suppliers. One marked finding from recent studies is that many Chinese industries show a combination of successfully tapping into international pools of knowledge on the one hand, and strong investments in national skills development and innovation capabilities on the other (Altenburg et al., 2008). Since the mid of 90s new factors have appeared in China providing more incentives to change their model of technology development towards one based on innovation-oriented dynamics. The new factors include: (1) accession of China to the World Trade Organization, (2) a new worldwide regime of intellectual property rights, (3) a growing presence of MNCs, (4) customers' needs becoming more demanding, and (5) tougher competition in world markets.

By a way of conclusion, in the two last decades the three Asian countries behind Japan have significantly caught up by targeting the technologically most progressive industries (Fagerberg F. and Godinho, 2006), and by creating R&D industrial sectors of sufficient size. They have developed and built up significant domestic capabilities for imitation then for innovation (Ernst, 2005; Lundvall et al., 2009). They have got a coherent national system of innovation and are becoming important international contributors to innovation (Dodgson and Gann, 2010). As a consequence, a population of researchers-inventors (including a highly productive class of inventors) has been established. Le Bas and Sung (2010) showed that the formation of this class of prolific inventors in Korea has been supported by the emergence and the development of technological capacities at both microeconomic and macroeconomic levels.

## 3. An evolutionary framework for inventor productivity, mobility and value of invention.

The point of view developed here finds its roots in the analysis of the growth of knowledge by recombination first systematically described by Weitzman (1996), and reused by Fleming (2001) and Antonelli (2008). In his approach the production of new knowledge is a process that cannot be modeled in general by analogy with the "discovery of new oil fields". Instead new knowledge is often produced by a recombination of scattered existing bits of knowledge. Weitzman (1996) supports his view with the following examples: "*The idea of an "electric light" is itself a hybrid, the first practical example of which was made in 1879, between the idea of "artificial illumination" and the idea of "electricity." The idea of an "electricity production and distribution network" was conceived by Edison in the 1880's as an explicit combination of the idea of "electricity" with the idea of a "gas distribution system," where electricity is essentially substituted for gas* (Weitzman, 1996: 209). His basic idea is that the expression of human imagination is "recombinatoric in essence."

We find this same important concept in Fleming and Szigety (2006), for whom the same mechanisms of creativity apply both in science and in technology. They start their analysis with a psychological model first elaborated by Simonton (1999). Inventors generate new ideas through combinatorial trials subject to psychological and social selection processes (Fleming, 2007). They note that individuals who simultaneously juxtapose, combine, and evaluate a stream of uncombined inputs will be more creative. Generative creativity is the assembly or rearrangement of existing components into new combinations. The more the inventor tries recombinant actions, the more he/she increases the likelihood of a productive hit. As a consequence we hypothesize a correlation between an inventor's total output and the likelihood that he/she finds inventions with high impact. "*A one-hit wonder is very unlikely......The most prolific inventor is the one most likely to invent a breakthrough*" (Fleming and Szigety, 2006: 340)[4].
The important output of such an analysis with respect to Weitzman's (1996) model is that it predicts a relation between inventor productivity and the economic value of new bits of knowledge produced. The new bits of knowledge may be embodied in inventions. Thus one can examine the behavior of inventors and the value of their inventions to find evidence of the Weitzman model's validity. This reasoning leads us to our first testable hypothesis:

H1. The more productive an inventor is, the more valuable his inventions will be on average.

Another aspect of this law can now be described. The inventors are more and less specialized as far as their technological competences are concerned. The level of specialization matters here. More specialized is an inventor more he works in the same field, more he will experiment in neighboring of his past invention, more he will be productive in terms of inventions. As a consequence we can consider the following complementary hypothesis[5]:

H1'. The more specialized an inventor is, the more productive he is

Recent strands of the literature dealing with invention value have proposed the strategic importance of inventor mobility as linked to invention value. The scale, determinants and effects of inventor mobility have been analyzed recently by Hoisl (2007 and 2009), Schankerman *et al.* (2006), and Trajtenberg (2004) among others. Hoisl, (2007) using European patents (a survey of 3049 German inventors), finds that an increase in inventor productivity (number of patents per inventor) decreases the number of moves from firm to firm. She tests the causality of the productivity of inventors on inventor mobility and finds that more productive *inventors are not more mobile from firm to firm*. For Hoisl, a move increases productivity (number of patents) but an increase in productivity decreases the probability of observing a move. Hoisl has investigated

[4] Fleming and Szigety (2006) make an inventory of the factors (technological and social-psychological variables) that have an influence on "the second moment of the creative outcome distribution" and consequently also affect the propensity to create breakthroughs. For example, among the important variables that have an expected positive impact on the variance of the distribution are: diversity of collaborators, dissolution of collaborative relationship, and changes of creative fields: as has been noted by many researchers, an inventor cannot invent alone, he/she invents collectively and within an "ecological context." As a consequence there are *organizational* influences on the evolution of the distribution of inventive behavior as well. Fleming (2007) finds empirical results in favour of this thesis.

[5] Our preliminary previous empirical studies on US patenting from 5 countries (USA, Japan, Germany France, U-K) show that more specialized inventors are more productive.

the differences in gains from a move between high and lower performing inventors. This point is particularly crucial for us because we want to assess the role of *prolific* inventors' mobility on their performance. Hoisl (2009) finds that

> inventors at the upper end of the performance distribution *(our prolific inventors*) are better able to benefit from a move to draw level with or to overtake non-movers in the post-move period. Whereas at the bottom of the performance distribution a higher level of education has a positive impact on inventive performance, education does not matter significantly at the upper end of the performance distribution.

Schankerman *et al*. (2006) have studied the mobility of inventors using patents in the software industry in the US. Their findings are in accord with Hoisl's: they show that the very productive inventors have a decreasing probability of moving between assignees as their careers progress (Schankerman *et al.,* 2006; 26). As far as value of inventions is concerned, Trajtenberg (2004) showed that inter-firm mobility is related to inventors' patents that are more technologically focused (more concentrated in technological categories) and those having more value (*i.e.* more cited). He pointed out that the Israeli inventors who tend to move more frequently *both across countries and between assignees* have the most highly-cited patents. But he concludes that there exists an endogeneity problem: we cannot determine whether it is the (high) value of invention that provokes the move or if it is the learning effect due to the move that tends to increase the invention's value. Schankerman *et al.* (2006) discuss the issue of inventor mobility in the framework of an inventor-employer matching process in the software industry. Asymmetric information between employer and employee about the value of an invention should be a relevant incentive for a move. They finally argue:

> we did not find support in the data that mobility is a matching process between the inventor and his employer, and that the quality of the inventor's patents increases after a move. If any, there seem to be some short term costs of mobility, which seem lower when moving to a larger firm.

We extend these studies by considering prolific inventors, the source, as we will show, of most innovation in the five countries, using several indicators of mobility as well as indicators of productivity and the value of inventions. In this paper we focus only on inter-firm mobility and technological mobility.[6]
Our model of knowledge creation through recombination takes into account the empirical evidence reviewed as follows: We suppose some bits of primary knowledge exist in the first time period. Through the process of recombination, some new bits of knowledge are created in the next time period. Note that the bits of previous knowledge that enter into the process of recombination continue to exist as useful knowledge. Significantly, the process of recombination does not stop in the second time period. It goes on. In this way, in the next time periods we will have additional new bits produced. The recombination process becomes more complex: it combines bits of recomposed knowledge with bits of "raw" knowledge. We think that the new elements of knowledge have more value than the primary bits of knowledge.

The knowledge that is used in recombination is both explicit and tacit. Codified explicit knowledge circulates, in general, through publications. The part that is tacit in nature is important in the process of recombination. Its structure depends on local factors such as firm organization, core technological competences of a region, etc.) and its diffusion is generally through the mobility of experts including inventors.

Inventors work in firms that are part of industries that are located in particular regions. We hypothesize that the set of bits of "primary knowledge" existing at the period of time under observation are differ according to these "places" (firms and industries as well as geographic regions). It may be that some bits or elements are common across places, but some are different. By moving (from firm to firm or from region to region) the inventor can get new bits of ideas that enter into the evolving processes of recombination. Before

[6] We use the terms technical and technological interchangeably Latham *et al*. (2011) present preliminary analysis of the scale of inventor *geographic* mobility for three European countries.

moving he might decide that he has exhausted the opportunities for successful recombinations in his current location. By moving he may find new fields for hybridizing or new avenues for creating new economically valuable inventions. He retains the bits of knowledge he had accumulated at the previous place but now works in a new knowledge environment. His potential for recombination becomes higher. Moreover due to social ties knowledge interactions persist even after formerly co-located individuals are separated after moves (Agrawal et *al.*, 2006).
Inventor mobility has always been recognized as a key mechanism for transferring tacit knowledge from one place to another between firms, industries, regions or countries (see Agrawal et *al.*, 2006). But a move is also a way to learn more, or to learn more quickly. In this sense mobility does not simply transfer knowledge from place to place as a spillover, but also increases the capacity to solve problems and basically increases the human capital of knowledge. Mobility as a mean for knowledge diffusion and extension matches the knowledge "reuse" approach of Langlois (2001), a type of increasing economy of scale at the core of economic growth process. Thus we expect that mobility affects: (1) the productivity of prolific inventors, as measured by their average number of inventions per year over their active inventive lives, and (2) the value of their inventions, measured as the number of citations a patent receives in the years after its application is filed.[7]

As a consequence we hypothesize:

H2. Following a move (from firm to firm, or from region to region) an inventor's productivity increases.

A corollary is:

H2'. An inventor who moves a lot is more productive than an inventor who moves less.

## 4. Data, Variables, and Measurement Issues

**4.1. Basic data.** We use data obtained from the National Bureau of Economic Research (NBER) Patent database project. We have data for individual utility patents issued by the United States Patent and Trademark Office (USPTO) from 1975 through 2010. The data file that we worked with includes all inventors, but we selected for this paper those inventors who come from China, Japan, Taiwan, and Korea and compare these inventors to three other regions: North America (includes US and Canadian inventors), Europe (UK, Germany, France, Italy, and Finland), and Australia (Australia and New Zealand). We use the basic NBER data on patents to compute a number of measures for individual inventors from the countries of our interest. We then limit the analysis to only the prolific inventors (the top 1 percent or top 5 percent of inventors in their countries measured by the number of patents that they have).

**4.2. The names game.** To produce a dataset with records containing aggregated measures, such as total number of patents or number of citations for an inventor, we needed to figure out which inventors authored each of the patents. Appendix A describes our procedures and notes problems that still exist in this area. The lower section of Table A2 shows how the numbers of inventors identified using our procedures in the four Asian countries and in the comparison regions are distributed among various technical categories of their inventions.

**4.3. Measuring prolificness.** The distribution of number of patents by inventors is clearly not normal; in fact it is highly skewed, with most inventors having few inventions and a few inventors having many inventions (Latham and Le Bas, 2011). Prior work has established that the prolific inventors produce many more than their proportionate share of patents and also tend to have more valuable patents (as measured by citations). We focus on these prolific inventors and seek to understand the determinants of their mobility, productivity and value.

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[7] Harhoff *et al.* (2003) have shown that the number of citations is a good proxy for the value of a patent.

No theory leads to a clear delineation of the number of patents needed to qualify an inventor as "prolific." In this paper we define a prolific inventor as an inventor with 15 patents or more patents. In our sample we have for 29225 Japan, 2 323 for Korea, for 1803 Taiwan, 157 for China.

**4.4. Accounting for inventor careers effects.** In our dataset we observe that there are some inventors with careers of patenting that span many years and others whose patents are all produced in a very short period. To account for this variation we measure the duration of an inventor's career (years from first to last invention, inclusive). We use duration to compute productivity, value, and inter-firm mobility on a per-year-of-career basis. In the data we have found that some inventors have long periods in which they do not patent. We attempt to incorporate this phenomenon in our analysis by measuring the maximum duration during which an inventor produces no patents in her career. We also observe that the career patterns of inventing are highly variable from prolific inventor to prolific inventor with some inventors having most patents at the beginning, some having most at the end, some showing a pattern of increase followed by decrease and still others having multi-modal To determine whether particular types of patterns are associated with our measures of productivity, mobility and value we crate measures of the temporal skewness and peakedness (kurtosis) of each inventor's own temporal patenting distribution. We believe that ours is the first anlaysis to utilize the temporal distribution patterns in this way.

Some investigators (e.g., Hoisl: 2006, 2007; Schankerman, Shalem and Trajtenberg: 2006) have tracked the numbers of patents and/or the numbers of citations that inventors have at various points in their careers. For example they us the number of citations an inventor has received prior to a move from one firm to another to predict some other magnitude. Implicitly, they assume that the move is based only on the past experience or performance of the inventor up to the time of the move. We adopt a different approach, essentially assuming that the number of inventions that an inventor eventually produces over his whole career is a measure of the innovative potential that the inventor has always had. We assume that employers make rational (mostly accurate) predictions about the future productivity of inventors when they are hired. So a manger can predict how productive an inventor will be over his career. This assumption allows us to compute a single measure of productivity or value over the inventor's whole career and use it as a characteristic of the inventor.[9].

**4.5. Measuring inventor productivity.** The simplest measure of an inventor's productivity is the number of patents he has obtained (patent grants) over a career. We adjust this for the career length to obtain the average number of patents per year as our productivity measure. Alternatives include the number of patent applications, instead of grants, or the sum of the numbers of design and utility patents. However, the number of patents per year is intuitively appealing, easily understood and computed and has been used by others, so it is our choice. We add to the simple average a measure of the dispersion of patenting activity over the inventor's career. The measure we use in our analysis is the inverse of dispersion; it is the Herfindahl-Hirschman Index for the time pattern of the number of patents in each year. We might have chosen the n-year concentration ratio instead but the HHI more appropriately gives extra weight to years of higher concentration. Hoisl (2007) suggests to use a "time concentration" variable that has a negative effect on inventor productivity.

**4.6. Measuring the value of an inventor's inventions.** The research literature on patents has, in the absence of any other measures for large patent data sets, accepted the number of citations as a proxy for the value of a patent (see the survey by Gay and Le Bas, 2005). The value of all of an inventor's patents can then be measured as the total number of citations they have received. The value of an inventor's patents might alternatively be measured as his average number of citations per patent, his average number of citations per year or his average number of citations per patent per year. The total number of citations fits with the concept of an inventor's potential. This measure may (then we call it citations per year) or may not be corrected for the duration of a career. It is our primary measure of value but we can also consider the number of citations per patent and the number of citations per patent per year.

[9] Volodin (2012), compares using only inventor team characteristics prior to a patent application with using the characteristics of the same inventors accumulated by the ends of their careers and finds that the two approaches do not yield greatly different results.

**4.7. Measuring inter-firm mobility.** The simplest way of identifying inter-firm mobility (an industrial structure move from one firm to another[10]) is to simply count the number of firms for which an inventor has worked and assume that the number of moves is this number minus one. However, this approach does not allow for the movement away from a firm and a subsequent return to it. Nor does such a measure consider the temporal pattern of the inventor's association with different firms. Another type of measure that might have been used is a measure of firm concentration, either the percentage of patents at n firms with the highest percentage (an n-firm concentration ratio) or a Herfindahl-Hirschman Index that accounts for the variability in the distribution of an inventor's patents across the firms for which he has worked. However, these measures also fail it consider the temporal pattern in any way (as a count of the number of firms also does not).

Still another way to measure inter-firm mobility is to list an inventor's patents chronologically[11] and to count a move each time the assignee of the inventor's patent changes. Such a count results in the maximum possible measure of the number of moves that an inventor makes. Even though this logic makes sense, certain patterns of assignees seem to call that definition into question. For example suppose that Inventor # 1 assigns his first patent to firm A, the second to firm B, and the third to firm A, the fourth to firm B and so forth through the assignment of the tenth patent to firm B. Inventor # 2 assigns her first five patents to firm A and the next five to firm B. Inventor # 1 will be counted as having 9 moves while Inventor # 2 will have only 1 move. This example is shown in Table 3. Surely this result does not adequately capture a strong sort of mobility well. In attempting to deal with this problem we have measured moves in several alternative ways. In the alternatives we consider whether or not the inventor returned to a prior assignee within some specified period of time. If so, we do not consider the temporary or transient change in assignee to be an indication of a strong variety of mobility. The last column of Table shows such a definition, requiring a two year persistence of a change to qualify for a move, applied to the data for Inventor #3. We know the numbers of moves measured under these definitions will be smaller than under the first definition. In results not reported here we have used several of these alternative definitions of mobility and have found, surprisingly, that our results are not sensitive to the definition of mobility.

**Table 2. Counting Numbers of Moves under Alternative "Move" Definitions**

| | | Inventor #1 | | Inventor #2 | | Inventor #3 | | |
|---|---|---|---|---|---|---|---|---|
| Invention | Year | Assignee | Move | Assignee | Move | Assignee | Move | Move (2 year) |
| 1 | 1 | A | 0 | A | 0 | A | 0 | 0 |
| 2 | 2 | B | 1 | A | 0 | B | 1 | 1 |
| 3 | 3 | A | 1 | A | 0 | A | 1 | 0 |
| 4 | 4 | B | 1 | A | 0 | B | 1 | 1 |
| 5 | 5 | A | 1 | A | 0 | B | 0 | 0 |
| 6 | 6 | B | 1 | B | 1 | A | 1 | 1 |
| 7 | 7 | A | 1 | B | 0 | A | 0 | 0 |
| 8 | 8 | B | 1 | B | 0 | B | 0 | 1 |
| 9 | 9 | A | 1 | B | 0 | B | 0 | 0 |
| 10 | 10 | B | 1 | B | 0 | A | 1 | 0 |
| Total Number of Moves | | | 9 | | 1 | | 5 | 3 |

**4.8. Measuring technological specialization.** Among the possible measures of technological **specialization** of inventors that we considered were a count of the number of different technological fields in which an inventor has worked and the number of changes from one technological field to another. Consequently we argue that a concentration measure would capture **specialization** well. We considered technology concentration ratios for the single highest concentration field and for the top 2 numbers. However, the Herfindahl-Hirschman Index (HHI) for technological fields appeals because of its greater emphasis (through the squaring of each field's percentage) on higher concentrations. We implemented the HHI at the level of

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[10] In this study we assume that moves between firms (assignees) provide an accurate picture of inter-firm mobility.

[11] Our data allow us to do this because we have application dates (including the day and the month), not just application years as in the publicly available NBER dataset that includes patents granted between 1975 and 2002)

six broad technological categories. As a consequence when the Herfindahl-Hirschman Index is high the inventor is specialized and conversely.

**4.9. Measuring geographic mobility.** We identify two kinds of interregional moves, inter-city moves and international moves. We refer to both as geographic mobility. We identify inventor geographic moves from changes in the inventor's place of residence from one patent to another. Our measures of mobility are then the numbers of international and inter-city moves that an inventor has made. International moves do not duplicate inter-city moves..

**4.10 The truncation problem.** Our patent data begin in one year (1975) and end in another (2010). For inventors whose entire inventive career falls within this span of years, there is no problem of bias from omitted years of activity before or after the sample period. However, for inventors who were already active prior to the sample or who remain active after the sample period, the truncation problem may be significant. All of our measures such as duration, citations and number of patents could be underestimated if the sample truncates the careers of inventors. In our data, it often takes several years before a patent begins to receive citations. If we use a "citations per patent" measure of patent value, the most recently granted patents could affect this measure negatively. To account for this potential bias, we eliminated from our dataset those inventors whose first patent was granted after 2007. In other work we have explored omitting all inventors with patents in either the first n or last n years, where the n values we have used are 2 and 3. Our results do not change significantly.

## 5. Models

In this paper we test a number of hypotheses about the relationships between and among inventors' productivities, their mobility in both technical and the inter-firm dimensions, and the values their patents create. The following four equations express our conceptual empirical framework for testing these hypotheses.

1) Productivity = f (Inter-firm Mobility, Technological specialization, Value of Patents, Temporal Patenting Pattern, Technical Field)

2) Inter-firm Mobility = f (Productivity, Technological specialization, Value of Patents, Temporal Patenting Pattern, Technical Field)

3) Value of Patents = f (Productivity, Inter-firm Mobility, Technological specialization, Temporal Patenting Pattern, Technical Field)

The parallel specifications of the equations are the result primarily of the limitations of our data. For example, while we are well-aware that there are both theories and empirical studies of productivity that highlight the roles of inventors' education and training, the capital available to them, the nature of the rewards system and the role of institutional constraints such as retirement ages and the nature of the patent system, we do not have those variables available to us at this time.[12] Similarly for both mobility and the value of patents many other variables have been suggested in theory and in other empirical studies. Consequently our work is not in the framework of those that attempt to propose and test comprehensive theories of the determinants of productivity, mobility or value. Instead ours is a partial approach. We examine the ways in which productivity, mobility and value influence each other given our limited range of knowledge about other variables. While we can include a few other variables as controls, such as the

[12] We are exploring a procedure that may permit us to link external data on inventors' characteristics to the patent data for at least a sample of inventors.

temporal pattern of an inventor's career, we essentially assume that all of the omitted variables can safely be "held constant" for our analysis.
The closely parallel specifications of the equations also may indicate simultaneity in the nature of the relationships among the variables.[13]

Table 3 lists the variables that we have available for the analysis. We don't have economic theory to guide either our selections of functional forms of the equations (log, linear, etc.) or our selection of various ways of specifying the particular variables that we will use. In the end we rely heavily on the empirical results in deciding which specifications to report. We have estimated and tested many alternative specifications. The combinations of alternatives ways of specifying the equations lead to large numbers of possible equation specifications that fit within our structural framework.[14]Appendix B gives the means of the variables.

[13] We deal with the potential endogeneity bias by modifying the specifications in our analysis by introducing instruments that permit us to control for it in a two-stage estimation framework

[14] For example, in the productivity equation, we have tested three different dependent variables: (1) (number of patents), (2) (number of patents)/(career duration), and (3) number of patents/(number of years with 1 or more patents). In addition we have estimated (1) with both Poisson and negative binomial distributions. So there are 4 dependent variables. We have tested alternative specifications for citations (3), for time pattern (2), for technical mobility (3) for inter-firm mobility (2), and for career duration (2). So, just for the productivity equation we have tested 4 x 3 x 2 x 3 x 2 x 2 = 288 equations for 5 countries = 1440 equations.

**Table 3. List of Variables**

| Variable | Definition or formula to calculate |
|---|---|
| Observation Units | Observations are individual inventors |
| **Inventor Career Measures** | |
| CAREER_DURATION | Year of last patent application - Year of first patent application + 1 |
| CAREER_TIME_GAP | The maximum number of years between two consecutive applications |
| **Inventor Productivity Measures** | |
| PATENTS_NUMBER | Number of patents |
| PATENTS_PER_YEAR | Patents_Number/Career_Duration |
| **Measures of Value of Inventor's Patents** | |
| CITATIONS_NUMBER | Sum of all citations for the inventor's patents |
| CITATIONS_PER_PATENT | Citations_Number/Patents_Number |
| **Measures of Inventor's Temporal Patenting Pattern** | |
| PATENT_TIME_CONC | Time Concentration = Share of patents in the year with most patents |
| PATENT_TIME_HHI | Herfindahl-Hirschman Index for patents per year |
| PATENT_TIME_SKEW | Skewness of patents per year distribution (NA if it cannot be calculated) |
| PATENT_TIME_KURT | Kurtosis of patents per year distribution (NA if it cannot be calculated) |
| **Inventor's Technical Category** | |
| TECH_CAT_1 | Chemical |
| TECH_CAT_2 | Computers and Communications |
| TECH_CAT_3 | Drugs and Medical |
| TECH_CAT_4 | Electrical and Electronic |
| TECH_CAT_5 | Mechanical |
| TECH_CAT_6 | Other (omitted category) |
| **Inventor's Technical Specialization** | |
| TECH_CAT_CONC | Share of inventions in the dominant category (among the six categories) |
| **Inventor's Inter-firm Mobility** | |
| FIRM_MOVES | Number of times inventor changed firms in the sequence of his patents |

## 6.Discussion of the results

**Table 4. Determinants of inventor productivity**

| Dependent Variable: PATENTS_PER_YEAR | Japan | Korea | Taiwan | China |
|---|---|---|---|---|
| RES_MOVES_CITY | -0.016 *** | 0.079 *** | -0.029 * | -0.161 * |
| RES_MOVES_INTL | 0.104 *** | -0.231 *** | 0.215 *** | 0,170 |
| CITATIONS_PER_PATENT | 0,001 | -0.032 *** | 0.018 * | 0,009 |
| TECH_CAT_CONC | 0.218 *** | 0.301 *** | 0.427 *** | 0,431 |
| FIRM_MOVES | 0.034 *** | 0.025 *** | 0.046 *** | 0.112 *** |
| PATENT_TIME_HHI | 1.697 *** | 1,273 | 5.519 *** | 3,658 |
| PATENT_TIME_SKEW | 0.013 * | 0.107 ** | 0,075 | 0,132 |
| PATENT_TIME_KURT | 0.087 *** | 0.125 *** | 0.079 *** | 0,027 |
| CAREER_DURATION | -0.021 *** | -0.039 *** | -0,028 | -0,150 |
| CAREER_TIME_GAP | -0.159 *** | -0.273 *** | -0.252 *** | -0,096 |
| TECH_CAT_1 | -0.044 ** | 0,064 | -0.285 * | -0,877 |
| TECH_CAT_2 | 0.148 *** | 0.419 *** | -0,050 | -0,172 |
| TECH_CAT_3 | -0.127 *** | 0,021 | -0,329 | -1,657 |
| TECH_CAT_4 | 0.126 *** | 0.209 * | 0.253 ** | -0,373 |
| TECH_CAT_5 | 0.083 *** | 0.571 ** | 0,094 | 0,649 |
| C | 2.335*** | 3.059*** | 2.347*** | 4.369*** |
| R-squared | 0,669 | 0,818 | 0,432 | 0,333 |
| Number of Observations | 29 225 | 2 323 | 1 803 | 157 |

*** p-value <= 0.01, ** p-value <= 0.05, * p-value <= 0.10

**Table 5. Determinants of inventor interfirm mobility**

| Dependent Variable: FIRM_MOVES/CAREER_DURATION | Japan | Korea | Taiwan | China |
|---|---|---|---|---|
| PATENTS_PER_YEAR | 0.531 *** | 0.601 *** | 0.262 *** | 0.092 ** |
| CITATIONS_PER_PATENT | -0.009 *** | 0.01 * | -0.024 *** | -0,013 |
| TECH_CAT_CONC | -0.36 *** | -0.46 *** | -0.499 *** | -0.565 ** |
| PATENT_TIME_HHI | -0.925 *** | -1.207 ** | -1.051 * | -0,199 |
| PATENT_TIME_SKEW | -0.038 *** | -0,042 | -0.112 *** | -0,076 |
| PATENT_TIME_KURT | -0,002 | -0.025 * | 0,014 | 0,013 |
| CAREER_DURATION | 0.04 *** | 0.067 *** | 0.081 *** | 0,078 |
| CAREER_TIME_GAP | -0,007 | 0,014 | -0.12 *** | -0.131 ** |
| TECH_CAT_1 | 0.081 *** | -0,102 | -0,122 | 0,156 |
| TECH_CAT_2 | 0,019 | -0.168 ** | 0.265 *** | 0,295 |
| TECH_CAT_3 | 0.094 *** | 0,054 | 0.252 ** | 0.82 ** |
| TECH_CAT_4 | 0,012 | -0,027 | 0.258 *** | 0,289 |
| TECH_CAT_5 | -0,018 | -0.447 *** | -0,055 | 0,202 |
| C | -0.824*** | -1.305*** | -0.138*** | 0,312 |
| R-squared | 0,691 | 0,869 | 0,525 | 0,241 |
| Number of Observations | 29 225 | 2 323 | 1 803 | 157 |

*** p-value <= 0.01, ** p-value <= 0.05, * p-value <= 0.10

**Table 6. Determinants of inventor patent value**

| Dependent Variable: CITATIONS_NUMBER | Japan | Korea | Taiwan | China |
|---|---|---|---|---|
| RES_MOVES_CITY | 0.007 *** | 0.011 *** | -0.008 | -0.008 |
| RES_MOVES_INTL | 0.062 *** | 0.023 | 0.126 *** | -0.009 |
| PATENTS_PER_YEAR | 0.059 *** | 0.107 *** | 0.182 *** | 0.186 *** |
| TECH_CAT_CONC | 0.076 *** | 0.097 ** | 0.226 *** | 0.184 |
| FIRM_MOVES | 0.000 | -0.004 *** | -0.001 | -0.002 |
| PATENT_TIME_HHI | -5.918 *** | -5.027 *** | -2.967 *** | -2.862 * |
| PATENT_TIME_SKEW | 0.201 *** | 0.463 *** | 0.394 *** | 0.386 *** |
| PATENT_TIME_KURT | 0.12 *** | 0.061 *** | 0.052 *** | 0.009 |
| CAREER_DURATION | 0.046 *** | 0.103 *** | 0.097 *** | 0.215 *** |
| CAREER_TIME_GAP | -0.131 *** | -0.1 *** | -0.074 *** | -0.158 *** |
| TECH_CAT_1 | -0.132 *** | -0.218 * | -0.24 ** | -0.063 |
| TECH_CAT_2 | 0.202 *** | 0.209 ** | -0.026 | 0.038 |
| TECH_CAT_3 | -0.004 | -0.132 | 0.008 | 0.662 |
| TECH_CAT_4 | 0.128 *** | 0.22 ** | 0.149 ** | -0.108 |
| TECH_CAT_5 | 0.022 | 0.029 | 0.019 | -0.182 |
| C | 5.623 | 3.995 * | 3.758 ** | -0.207 |
| R-squared | 0.413 | 0.882 | 0.715 | 0.776 |
| Number of Observations | 29,225 | 2,323 | 1,803 | 157 |

*** p-value <= 0.01 ** p-value <= 0.05 * p-value <= 0.10

Table 4 shows the estimated coefficients for the inventor productivity relation, Table 5 for the determinants of inventor inter-firm mobility, and Table 6 for inventor inter-city mobility.

For the inventor productivity relation the regressions have in general high R-square values. Japan and Korea have the highest R-squares. As regards the productivity model we find that the coefficient for inter-firm mobility is always positive, indicating that inventors with many moves are more productive and conversely. Of course we cannot infer any causal relation between the two. In a frame of descriptive regressions we do not know if it is this type of mobility that determines inventor productivity or the reverse. Our regressions simply show that the relationship between mobility and productivity well established by the literature is clearly confirmed. Interestingly the coefficient is higher fir China. As to the sign of the coefficient related to intercity mobility we did not find consistent results. The sign is negative and significant for 3 countries but positive for Korea. As regards international mobility, the coefficient is positive for Korea, but significantly negative for Japan and Taiwan indicating that the inventors who move more have lower level of productivity (or conversely). Such a result was not expected since Taiwan is the country for which the inventor mobility was high as noted previously. Strangely this set of results is the accurate reverse of the results for intercity mobility. A few studies take into account theses aspects of mobility. The coefficient related to the inventor degree of technological specialization is always positive (excepted for China). It indicates that more specialized inventors are more productive than those less specialized. This result is in lines with the evolutionary view of the determinants of inventor productivity (our study on the five large countries in terms of patenting confirmed this trend, see Latham et al., 2012). In general temporal concentration of inventions has a positive effect on inventor productivity. This result appears in opposition with the finding by Hoisl’s (2007) for a population of German inventors. One reason for the difference may because we study only the more productive inventors. For this variable differences appear between Western and Asian countries. For instance the result is not valid for Korea and China. Career duration has a negative coefficient (except for Taiwan and China). Our previous study show that is the general trend (see Latham et al., 2012) expressing the idea that inventors with a longer career are less productive (to some extent this last result is in accordance with the result related to time concentration). It might be that for China one reason for the difference is the very short time period in which we observe inventor productivity because of China’s late entry into patenting. Finally the variable CAREER_TIME_GAP matters as expected: inventors with a long time period without patented inventions have lower productivity (the two directions of causality are equally possible). This trend is pervasive and matches the situation of 3 Asian countries (the case of China is particular: fewer inventors and a shorter observation period).

For the inter-firm mobility model (see table 5) we note that inventor productivity has a positive impact on the scale of inter-firm mobility for all four countries of the sample (confirming the results stemming from the first estimated equation). But we still cannot interpret this result in causal terms. Strong inventor technological specialization is related to less mobility. And conversely less specialized inventors are more mobile. This is relevant for all the Asian countries. Inventor patent value is a “fuzzy” determinant of inter-firm mobility. The variable related to invention value is positive for Korea (but weakly significant), negative for Japan and Taiwan or not significant at all for China. Europe and the USA the coefficient of this variable is negative as well is (see Latham et al., 2012). It means (if our data and statistical treatments are good) there is no successful competition in Asian countries for attracting inventors with high invention value (which is in accord with what we know about the employment system in the large Japanese firms). We know that countries differ through their institutional arrangements. In this context the Korean case is atypical. Preliminary treatments using other definitions of prolificness (top 1% and top 5% instead of 15 patents) showed that the trend regarding the relation value/mobility was not the same according the definition retained. Of course additional analysis will be necessary before we have definitive insights.

Temporal concentration of patenting is always negative and very often significant (China excepted). This result is partly due to a mechanical effect; if the inventor's patenting is really concentrated in a short time period he has fewer opportunities for moving. The opposite is true when we consider the variable CAREER_DURATION. A longer career generates many opportunities for moving. The coefficient related to CAREER_DURATION is positive for Asian countries and significant for 3. The variable CAREER_TIME_GAP has negative and significant effects for many countries (see Latham et al., 2012). Inventors with a long time period of time without patenting (all other things being equal) move less (we know from the first regression that they are less productive as well). As far as Asian inventors are concerned the "law" is not valid for Japan and Korea.

Table 6 gives the results for the estimation of inventor patent value. One among the main findings is that the evolutionary law is everywhere confirmed (with a set of control variables). The coefficient of related to inventor productivity (PATENT_PER_YEAR) is always very significantly positive. It is higher in the two countries that catch up later: Taiwan and China[15]. Technological specialization matters positively for the four countries: more specialized are the inventors, more valuable their patents are. It must be noted that here it is a pure effect of specialization, the effect of inventor productivity on patent value has been take into account.

Is there an effect of inter firm mobility on the valuation of patents? The coefficient related to this type of mobility is significant for Korea only but negative (and exceptionally weak). All thing being equal there is no effect of inter firm mobility once we control for inter city and international mobility. International mobility plays a role (positive of course) for two countries. For Taiwan what it was expected (see section 1) and for Japan what is amazing knowing that this countries is more closed in terms of technological activities. For correctly interpreting this last evidence further treatments and analysis would be necessary in the lines recently suggested by Alnuaimi *et al.* (2012) for understanding the impact of local and foreign mobility in India. We observe that patenting time concentration has a positive impact in all the countries, the same for career duration. The first evidence tell us that inventors concentrating their inventions in a short time period produce inventions with less value than those dispersing their inventions on a longer time period. The second impact due to the length of an inventor career could lay out the positive impact of the inventor learning dynamics. By contrast the negative sign of CAREER_TIME_GAP tend to diminish the positive effect of learning.

[15] Our previous research (Latham et al., 2010) on the drivers of inventor invention value showed that inventor productivity is a consistently positive and significant determinant of the value of patents (with very high coefficients).These results confirms the findings of Gambardella et al. (2005) who used the PATVAL survey (7000 patents). They found that the characteristics of the inventor, in particular his past number of patents, is the main determinant of the private value of inventions and more important than the characteristics of the organization in which he is employed. Our previous empirical research (see Gay et al., 2008) has also confirmed this result. Our previous empirical study concerned the top five countries in terms of size of technological activities (US, Japan, Germany, UK, and France). Our data set encompassed all US patents applied between 1975.

## Conclusions

First the set of variables we have constructed and tested have been found to be highly relevant for explaining inventor productivity and mobility. The hypotheses put forth by the evolutionary tradition appear to have been affirmed, in particular the relationship between productivity and the value of invention. This relationship is relevant for all the Asian countries, in spite of their having different levels of technological development and having diverse experiences in the technological catching up processes. This finding provides support for the strength of this “law”.

We have provided new insights through a set of newly designed variables. For instance CAREER_TIME_GAP has significant explanatory power. One interesting finding is that the role played by inventor technological specialization that differs for inventor productivity and mobility. This variable is found to matter significantly in all the three regression models. The set of control variables related to inventor temporal patenting patterns have almost always significant impacts. Their study could be the core of a new research.
With respect to our goal of comparing the dynamics of inventor productivity and mobility according to the types of countries, the main finding is that there is not much difference across Asian countries. The main trends are shared by the four countries: impacts of inter firm mobility on inventor productivity, impact of inventor specialization on inter firm mobility, impact of inventor productivity on the value of his patents. Value is a “fuzzy” determinant of inter-firm mobility. Interestingly the variable related to invention value is negative or not significant at all. It means (if our data and statistical treatments are good) there is no competition in Asian countries for attracting inventors with high invention value (which is in accord with what we know about the employment system in the large Japanese and Korean firms).

Surprisingly we expected to find clear-cut differences due to the difference in the level of technological development between China and Japan, but it is not the case. We thought that the differences related to the type of dominant innovating firms between Korea (very large firms) and Taiwan (Silicon Valley firms) will also entail notable differences in the regression results. In general this is not the case.

For some phenomena we record differences across Asian countries: the role of international mobility differs between Korea and Taiwan, the “law” of inventor technological specialization does not play for China in the patent value equation. These observed differences may be due to the specific national institutional settings, the different industrial/technological structures, or the differences in composition between the large conglomerate firms of Korea and the smaller, Silicon Valley type, firms of Taiwan. However, because the sizes of our samples of prolific inventors are very different across the countries, and are quite small in some cases, one must interpret the comparative results with caution.

Finally, our results show that, with regard to the production of new technological knowledge (in short the collective and complex process of invention) the Asian countries that we have examined do not differ much from the “old industrialized” countries. In both we find that (1) inventor inter-firm mobility and inventor productivity are strongly and significantly linked, and (2) inventor productivity and value of inventions are related for all countries (or the group of countries). The results confirm our previous findings (see Latham *et al.*, 2012). As a consequence it is tempting to consider them as two (general) laws of creativity. But there are differences between the Asian countries and the “old industrialized” countries. For instance geomobility (intercity or international mobility) has different consequences on inventor productivity. The determinants of inter firm mobility are equally various. At this stage of the research it is still difficult to tell whether or not these differences are clearly due to national-specific factors or are a product of the quality of the data we use.

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## Appendix A. How We Play "The Names Game"

To produce a dataset with records containing aggregated measures, such as total number of patents or number of citations for an inventor, we needed to figure out which inventors authored each of the patents. We used a process similar to that by Melamed et. al: 2006. The process involves the following steps:

> Step I. Select a group with the last names that sound similarly (using the Soundex method). Unfortunately, because of different spellings of many foreign inventors' names and other errors in the data, we cannot restrict this list of inventors to only the last names that spell the same way.
>
> Step II. Run automatic pair-wise comparisons between all inventors in the list with similar-sounding names, assigning points for matching fields. Table A1 and Table A2 provide some examples of the rules that are used to assign points.

**Table A1. Point system for comparing inventors using their last name (LN), first name (FN), middle name (MN) and Soundex version of these names, S(LN) and S(FN)**

| Last name | First name | Middle Name | S(LN) | S(FN) | Points |
|---|---|---|---|---|---|
| same | | | same | | 60 |
| same | same | | same, rare | rare | 90 |
| same | same | | same | rare | 70 |
| same | same | | same | | 50 |
| same | different | | same | same | 30 |
| same | | same | same | | 100 |
| same | | 1st letter same | same | | 80 |
| same | | | same, rare | | 10 |

| Last name | First name | Middle Name | S(LN) | S(FN) | Points |
|---|---|---|---|---|---|
| diff | | | same | | 30 |
| diff | same | | same | | 25 |
| diff | same, rare | | same | | 30 |
| diff | different | | same | same | 15 |
| diff | | same | same | | 50 |
| diff | | 1st letter same | same | | 40 |
| diff | | | same, rare | | 5 |

| Middle Name | Length of MN | 1st letter | 1st letters | Points |
|---|---|---|---|---|
| not empty, diff | 1 | different | | -500 |
| not empty, diff | >1 | | different | -500 |

**Table A2. Point system for comparing inventors using their address (top) and patent characteristics: assignee name and technical classification (bottom)**

| Country | State | City | Street address | Points |
|---|---|---|---|---|
| | | same | | 60 |
| | | | 1st 5 letters same | 95 |
| | | | same | 130 |
| same | | | | 10 |
| "US" | same | | | 10 |

| S(Assignee name) | Tech field (2 digit) | Tech category (1 digit) | Points |
|---|---|---|---|
| same | | | 60 |
| | same | same | 40 |
| | different | same | 20 |

Step III. Use a threshold score to determine whether the two inventors are the same person or not. We tried several different thresholds and chose 140 as the one that has worked well with most of the names in the database. We are still in process of finding a better scoring system as well as a threshold that would be able to correctly identify whether two names belong to the same inventor or not.

Overall, the names problem is far from being solved. We used the identical process for matching inventors in all of the countries in our paper, however we believe that the Soundex method could be modified to get a better result for the names in languages that are not closely related to the English language. Another way to improve the matching process would be to use co-inventor data (of different levels). We intend to implement this last strategy in the near future.

## Appendix B. Means of the variables

| | China | Japan | Korea | Taiwan |
|---|---|---|---|---|
| CAREER_DURATION | 9,745223 | 21,24291 | 15,4365 | 14,59068 |
| CAREER_PROD_YEARS | 7,210191 | 13,92181 | 11,37624 | 10,34443 |
| CAREER_TIME_GAP | 2,904459 | 4,726536 | 3,619888 | 3,718802 |
| PATENTS_NUMBER | 32,29299 | 39,75319 | 56,6087 | 38,52191 |
| PATENTS_PER_YEAR | 3,876823 | 1,871579 | 3,259482 | 2,81325 |
| PATENTS_PER_PROD_YEARS | 4,612576 | 2,590198 | 4,045682 | 3,569334 |
| CITATIONS_NUMBER | 91 | 330,5868 | 221,2665 | 216,7659 |
| CITATIONS_PER_PATENT | 2,775811 | 8,141283 | 3,674203 | 5,178668 |
| PATENT_TIME_CONC | 0,359095 | 0,205275 | 0,257612 | 0,27172 |
| PATENT_TIME_HHI | 0,250092 | 0,121743 | 0,161414 | 0,174267 |
| PATENT_TIME_SKEW | -0,59806 | -0,30152 | -0,69796 | -0,48063 |
| PATENT_TIME_KURT | 1,436631 | 0,372789 | 1,064859 | 1,144948 |
| TECH_CAT_CONC | 0,847134 | 0,672814 | 0,629789 | 0,716029 |
| TECH_CAT_HHI | 0,847134 | 0,672814 | 0,629789 | 0,716029 |
| FIRM_MOVES | 8,375796 | 15,8685 | 26,69307 | 16,30727 |
| TECH_CAT_1 | 0,057325 | 0,20657 | 0,077486 | 0,033278 |
| TECH_CAT_2 | 0,299363 | 0,26077 | 0,377529 | 0,163616 |
| TECH_CAT_3 | 0,006369 | 0,02905 | 0,009901 | 0,01442 |
| TECH_CAT_4 | 0,528662 | 0,253379 | 0,457598 | 0,613977 |
| TECH_CAT_5 | 0,070064 | 0,187066 | 0,033147 | 0,087077 |
| TECH_CAT_6 | 0,038217 | 0,062652 | 0,044339 | 0,087077 |
| OBS | 157 | 29225 | 2323 | 1803 |